Reproducibility assessment of the observed links between Arctic sea-ice variability and the Euro-Atlantic atmospheric circulation in CMIP5 present climate

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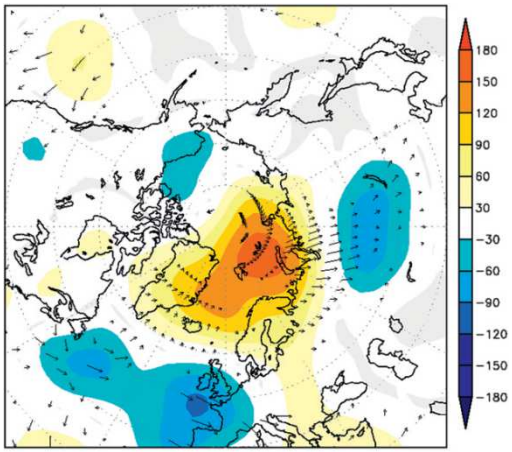
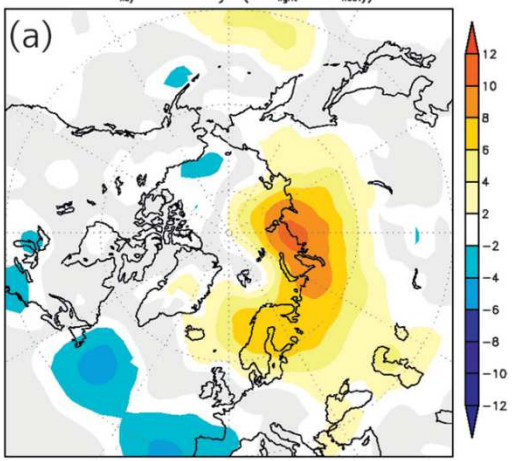
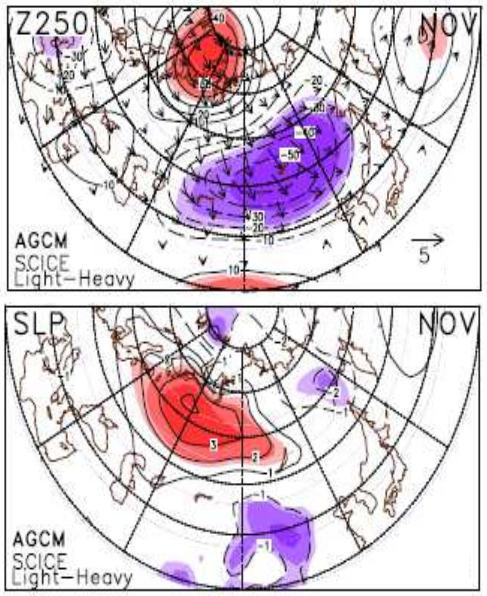
NACLIM Annual Meeting, 2015

Z250 / WAF (DJF)





Inoue et al. (2012, GRL)

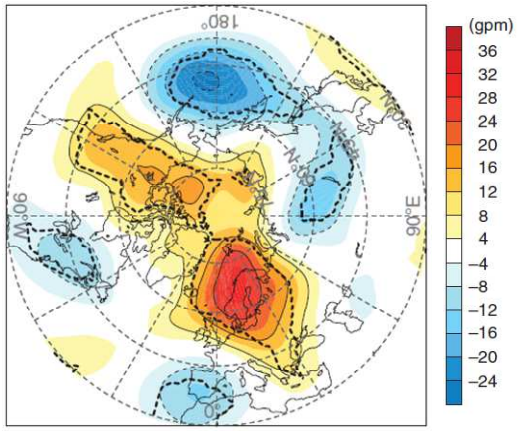


Honda et al. (2009, GRL)

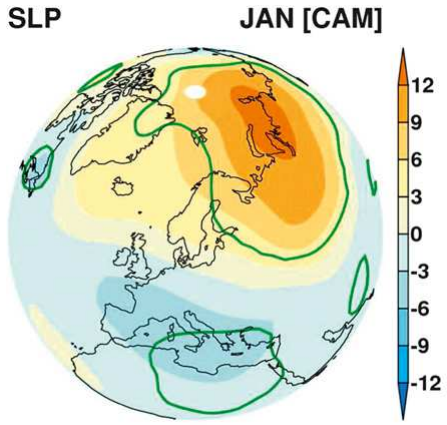
might be non-linear to SIC reduction!

Petoukhov and Semenov (2010, JGR)

ΔZ500 for ND, CAM5

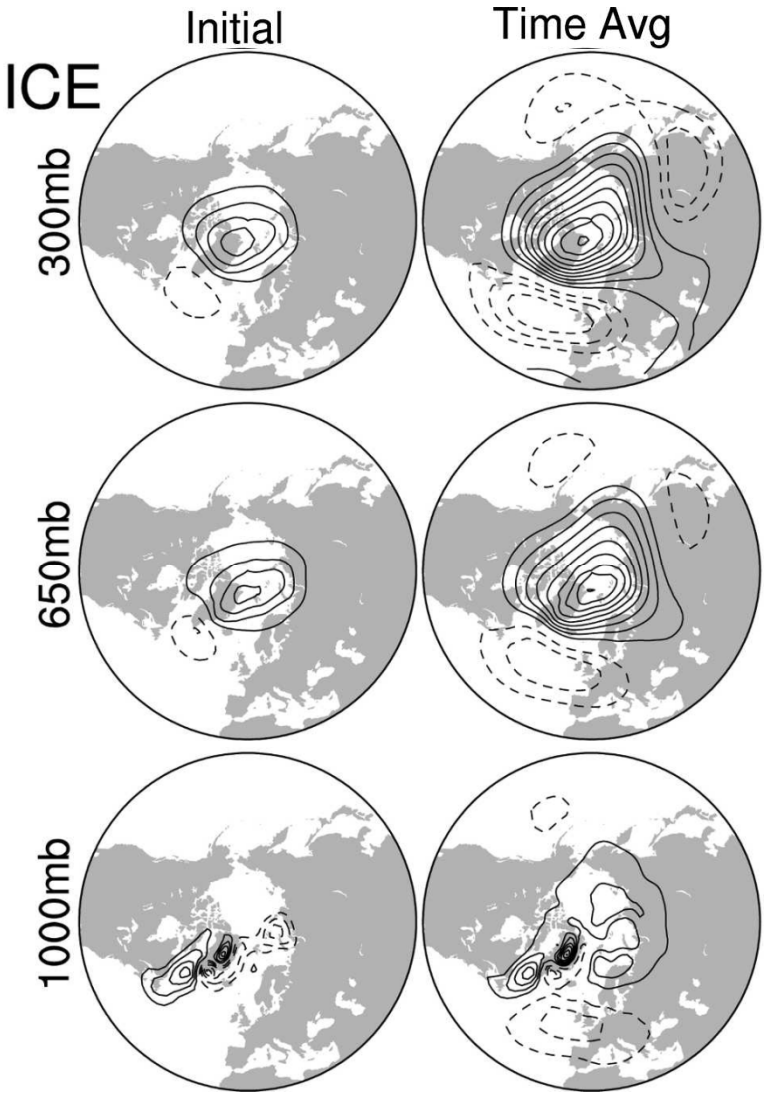


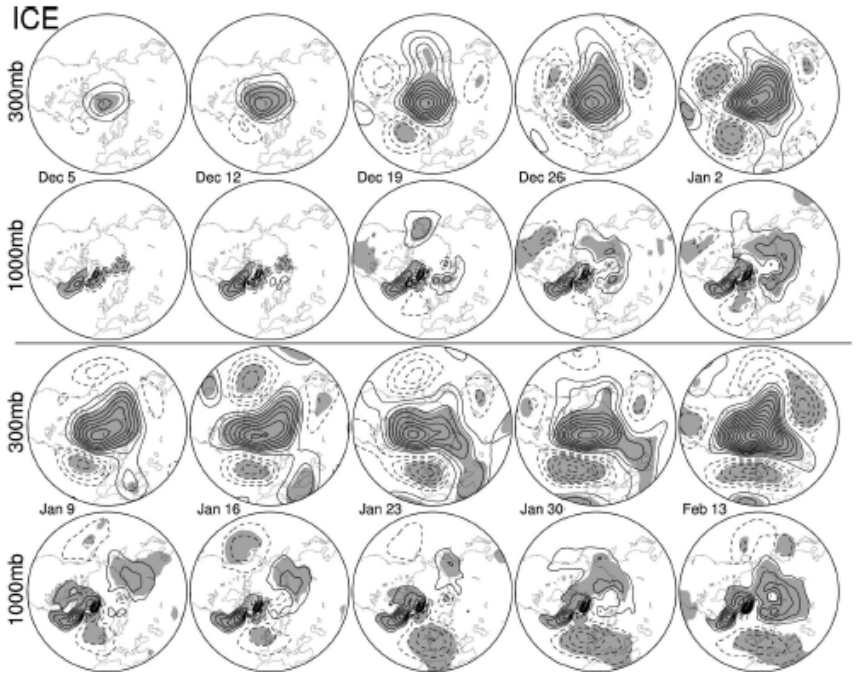
Kim et al. (2014, Nat.Comms)



Grassi et al. (2013, JCLIM)

RECENT REVIEWS: Bader et al. 2011; Cohen et al. 2014; Vihma 2014; Walsh 2014; Gao et al. 2015; Overland et al. 2015

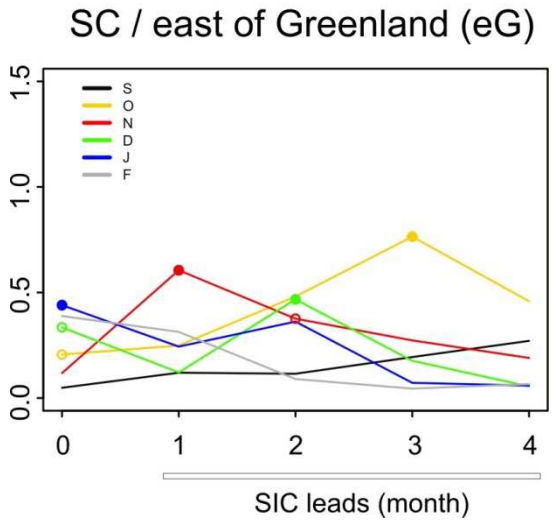




the equilibrium response to SIC reduction over G-B Seas, which projects on the negative NAO, is reached in about two months

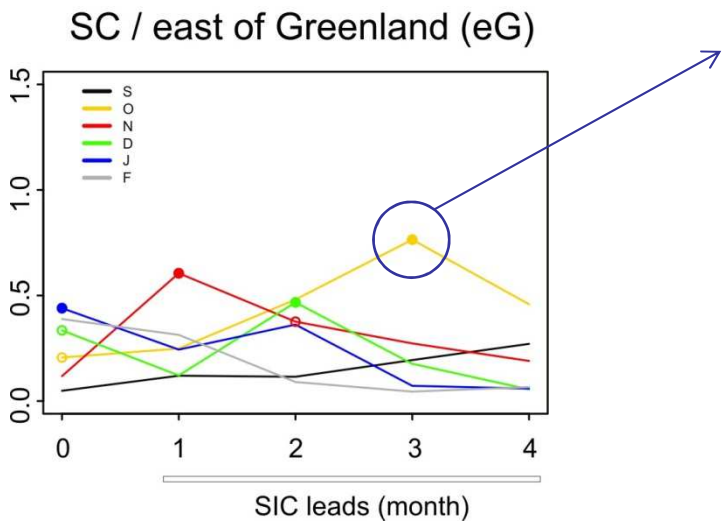
Deser et al. (2007, JCLIM)

HadISST



- detrended, monthly anomalies;
period 1979-2013;
target – cold season (Sep-to-Feb)

HadISST



might be linked to winter blocking over Eurasia

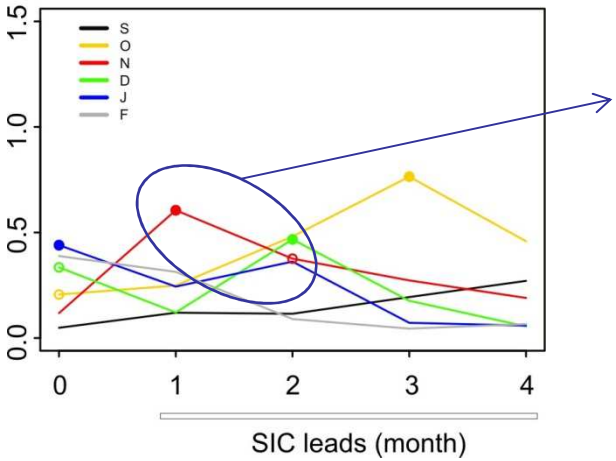
Mori et al. 2014 (Nat.Geosci); García-Serrano et al. (2015, JCLIM)

but the lead-time is longer than the expected atmospheric response time to SIC forcing

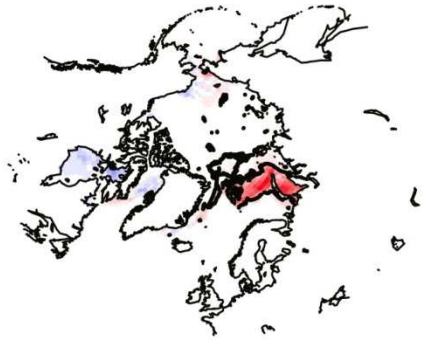
- detrended, monthly anomalies;
period 1979-2013;
target – cold season (Sep-to-Feb)

HadISST

SC / east of Greenland (eG)

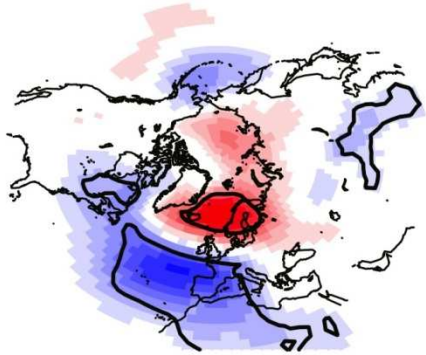


a) **MCA-SIC/eG$_{NOV}$ x SIC (nov)**



sig.lev.(SC)=6%

b) **MCA-SIC/eG$_{NOV}$ x SLP (jan)**

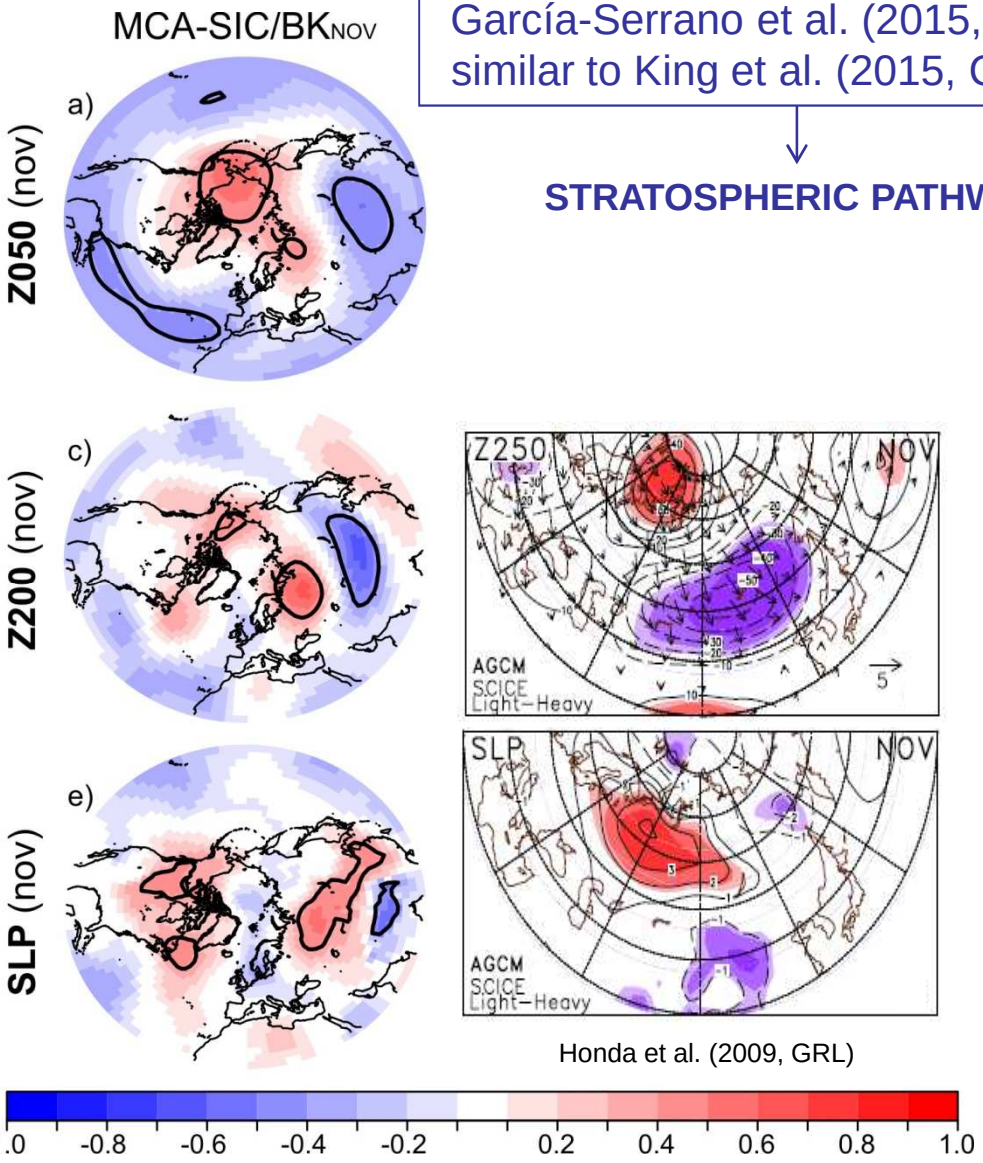


- detrended, monthly anomalies;
period 1979-2013;
target – cold season (Sep-to-Feb)

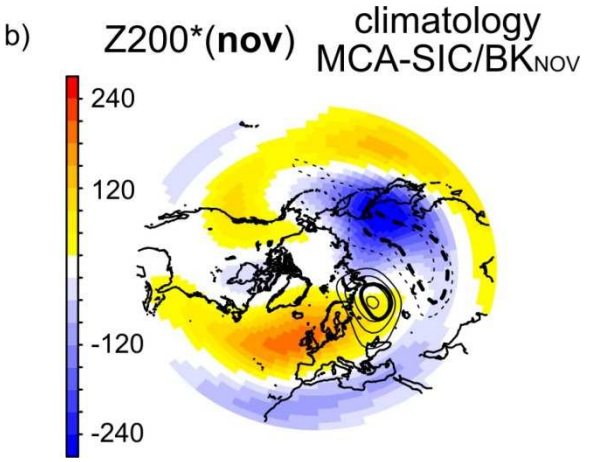
García-Serrano et al. (2015, JCLIM); similar to King et al. (2015, ClimDyn)

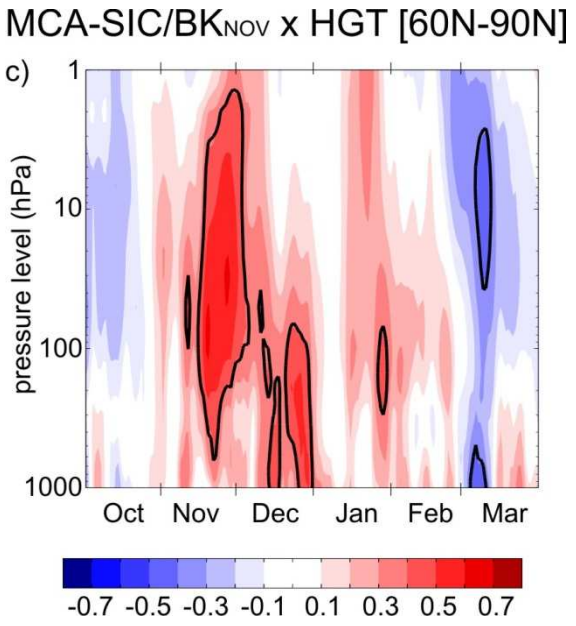
↓

STRATOSPHERIC PATHWAY



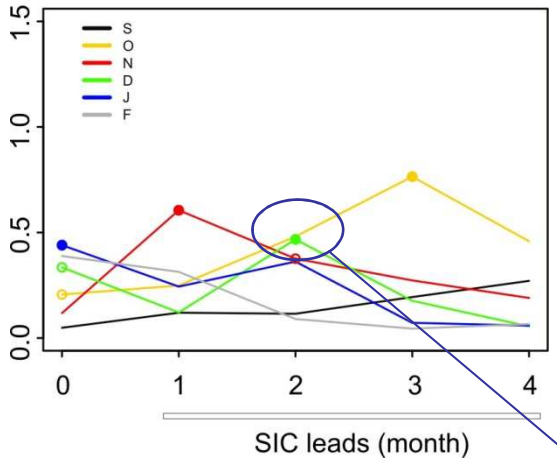
Honda et al. (2009, GRL)





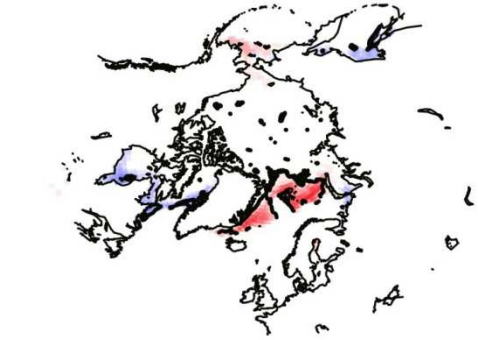
HadISST

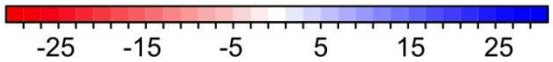
SC / east of Greenland (eG)



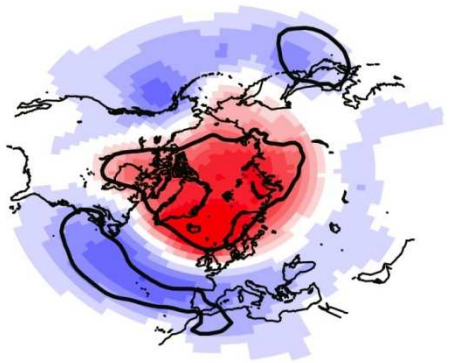
- detrended, monthly anomalies;
period 1979-2013;
target – cold season (Sep-to-Feb)

c) **MCA-SIC/eG$_{DEC}$** x SIC (**dec**)





d) **MCA-SIC/eG$_{DEC}$** x SLP (**feb**)



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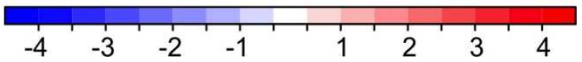
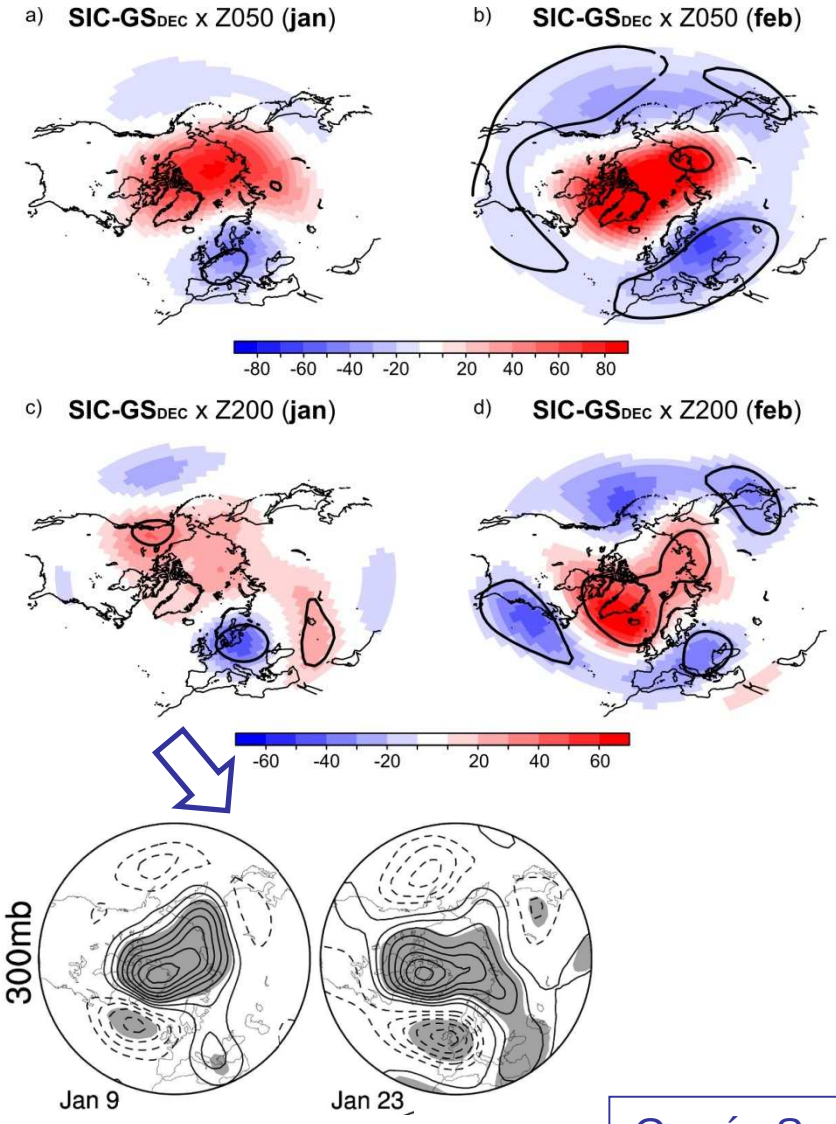
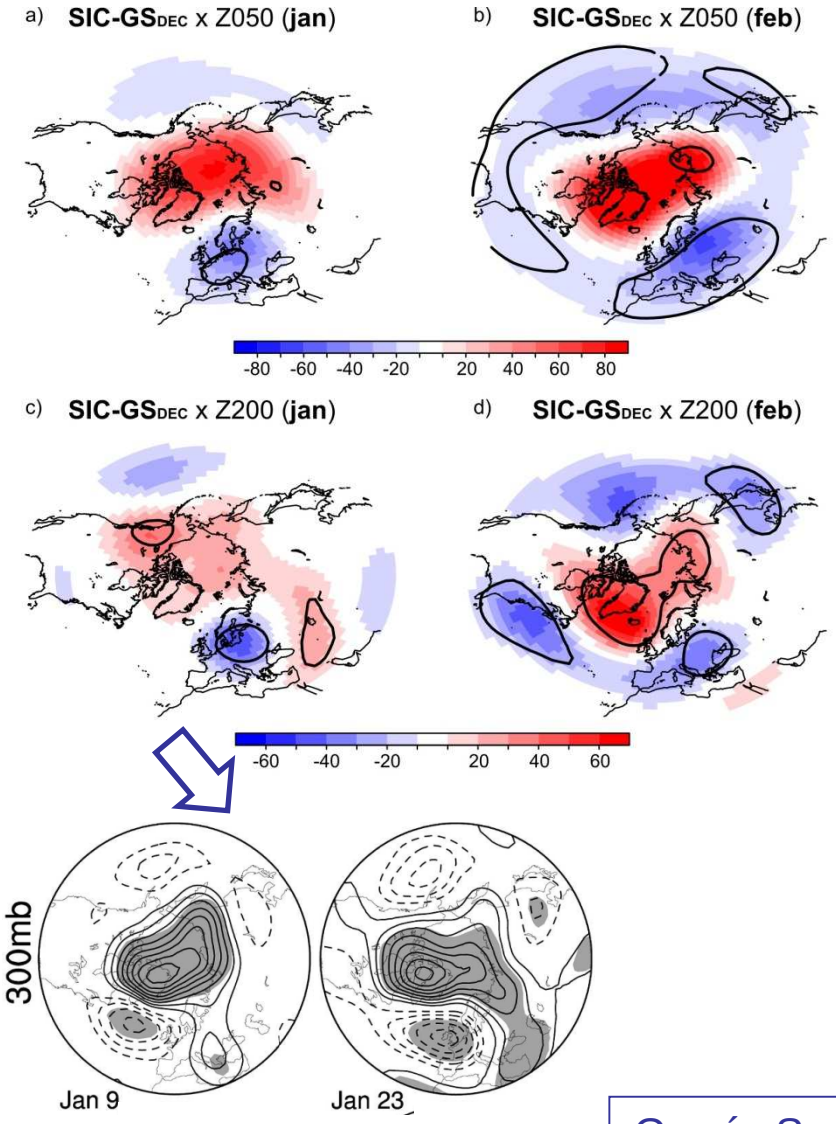


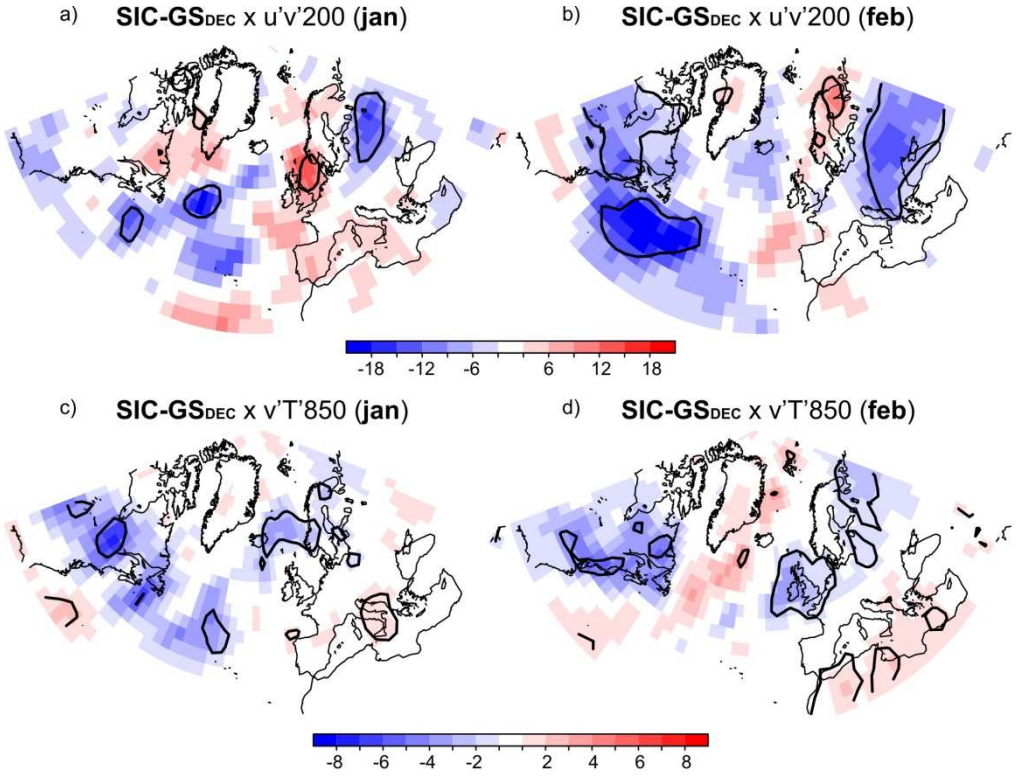


Deser et al. (2007, JCLIM)

García-Serrano and Frankignoul (2015, ClimDyn – under review)



Deser et al. (2007, JCLIM)

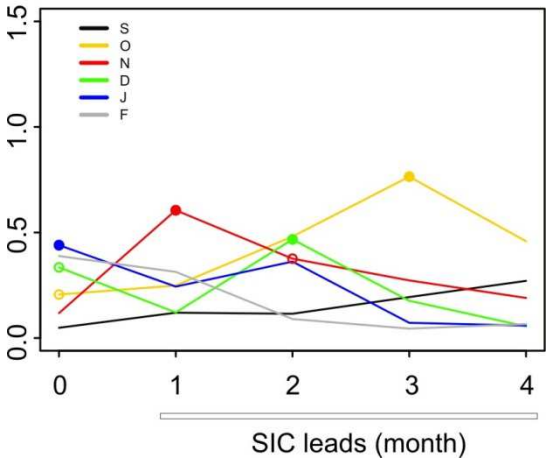


TROPOSPHERIC DYNAMICS

García-Serrano and Frankignoul (2015, ClimDyn – under review)

HadISST

SC / east of Greenland (eG)



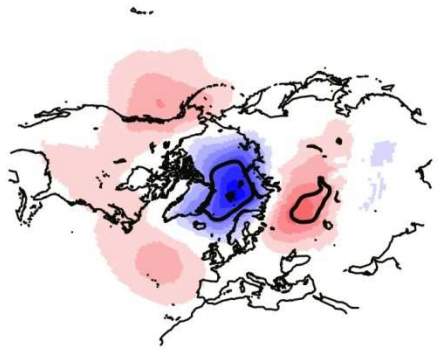
- detrended, monthly anomalies;
period 1979-2013;
target – cold season (Sep-to-Feb)

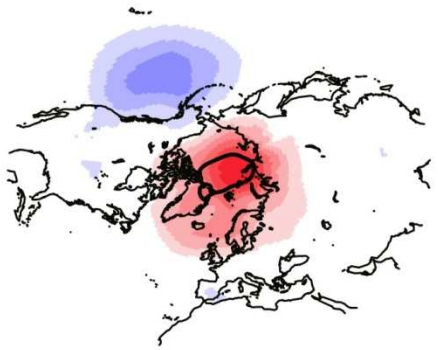
- **CMIP5**: no multi-model, each model individually;
CCSM4 (5mb), CNRM-CM5 (10mb), EC-EARTH2.3 (3mb), GFDL-CM2.1 (10mb), HadGEM2-ES (4mb), IPSL-CM5A-LR (3mb), MPI-ESM-MR (3mb), NorESM1-M (3mb) - HISTORICAL RUNS

CCSM

a) **MCA-SIC/eG$_{DEC}$** x SLP (**dec**)

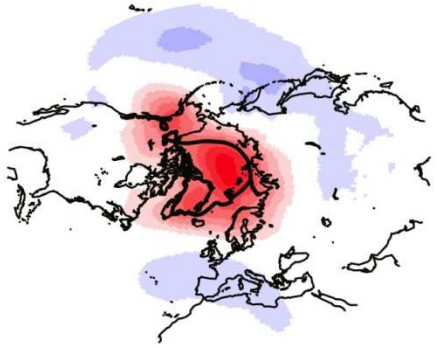
b) **MCA-SIC/eG$_{DEC}$** x SLP (**jan**)





c) **MCA-SIC/eG$_{DEC}$** x SIC (**dec**)

d) **MCA-SIC/eG$_{DEC}$** x SLP (**feb**)



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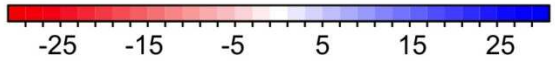
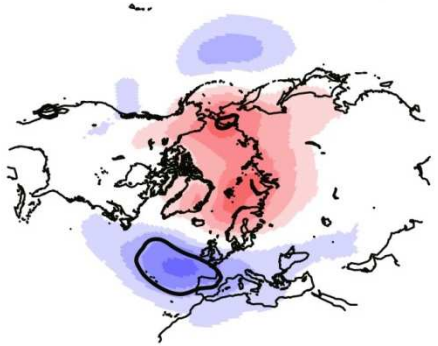
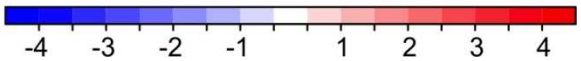
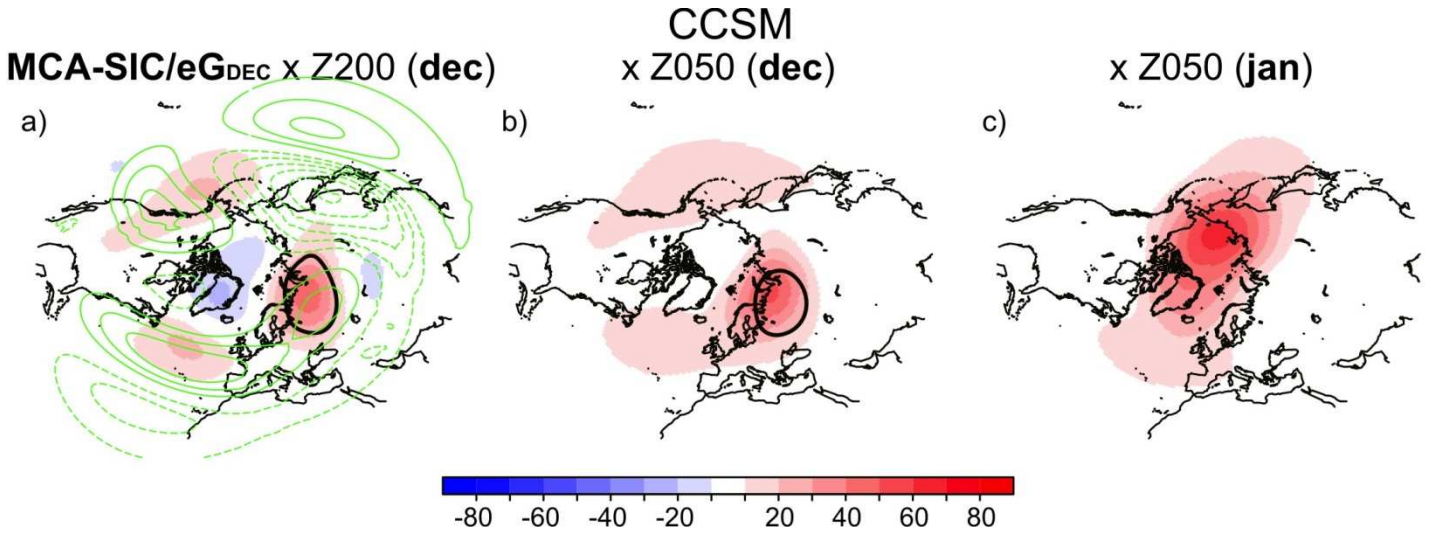


e) **MCA-SIC/eG$_{DEC}$** x SLP (**mar**)





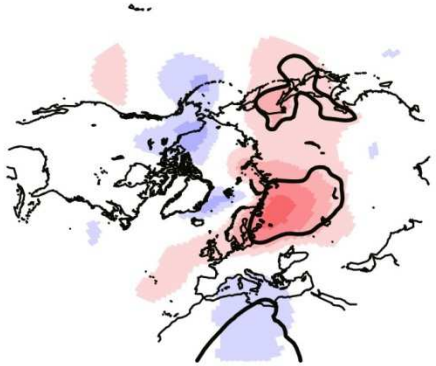
- eG **Dec** / SLP **Feb**: resembles the observed MCA mode (with 2-month lag); SLP anomalies over Polar Cap change sign from Dec to Jan, and amplify into Feb (statistical significance as well); lagged SLP anomalies over North Atlantic become stronger in Mar (also Z200), likely eddy-driven



- eG **Dec** / SLP **Feb**: anomalous anticyclone over northern Siberia (Z200) consistent with direct linear response to SIC reduction (see SLP). there is no clear weakening of the polar vortex in Dec (Z050), and in Jan it's not significant; it becomes significant in Feb (not shown), once the AO-like anomaly is established in the troposphere (Jan-Feb), suggesting that tropospheric dynamics is key in driving the lagged anomalies whereas the stratosphere acts as positive feedback (e.g. Ambaum and Hoskins 2002)

CNRM

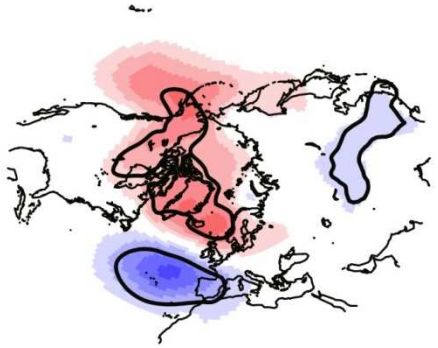
a) **MCA-SIC/eG$_{DEC}$** x SLP (**dec**)



- eG **Dec** / SLP **Jan**: resembles the observed MCA mode with SIC in Nov (with 1-month lag), but different timing (Dec->Jan vs Nov->Dec); it yields anomalous anticyclone over Siberia preceding the negative NAO-like pattern

b) **MCA-SIC/eG$_{DEC}$** x SIC (**dec**)

c) **MCA-SIC/eG$_{DEC}$** x SLP (**jan**)



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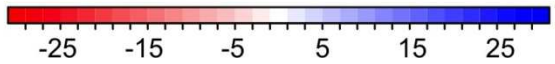
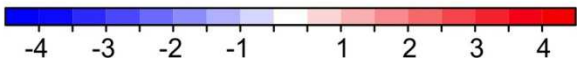
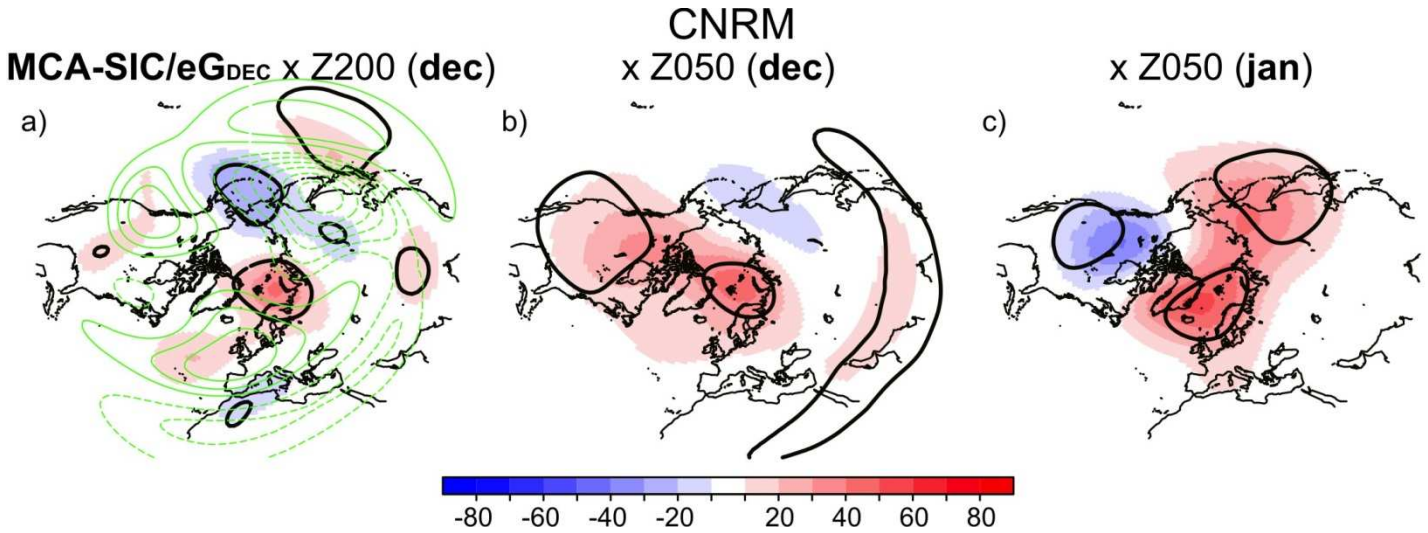


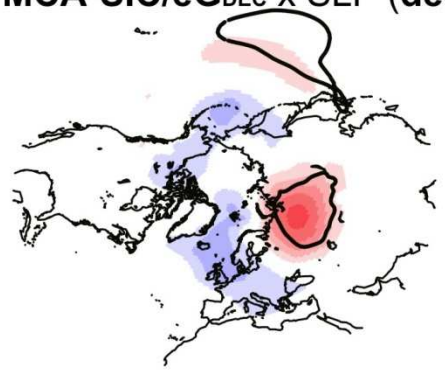




- eG **Dec** / SLP **Jan**: anomalous anticyclone over northern Siberia (Z200) consistent with direct linear response to SIC reduction (see SLP); Z200 anomalies show some downstream extension, with negative anomalies over eastern Eurasia-western North Pacific (as shown in observations). there is a weakening of the polar vortex in Dec (Z050), projecting on a wavenumber-2 structure, preceding the establishment of the negative NAO-like patter at surface (in Jan), suggesting that a stratospheric pathway could act as driving mechanism

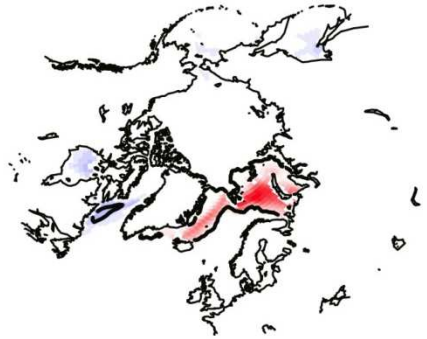
EC-EARTH

a) **MCA-SIC/eG$_{DEC}$** x SLP (**dec**)

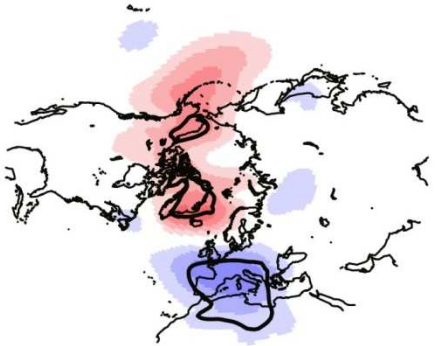


- eG **Dec** / SLP **Jan**: as in CNRM, it resembles the observed MCA with SIC in Nov, but different timing (Dec->Jan vs Nov->Dec); it also shows anomalous anticyclone over Siberia preceding the negative NAO-like pattern

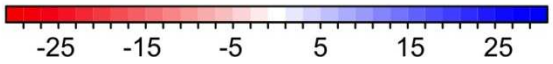
b) **MCA-SIC/eG$_{DEC}$** x SIC (**dec**)

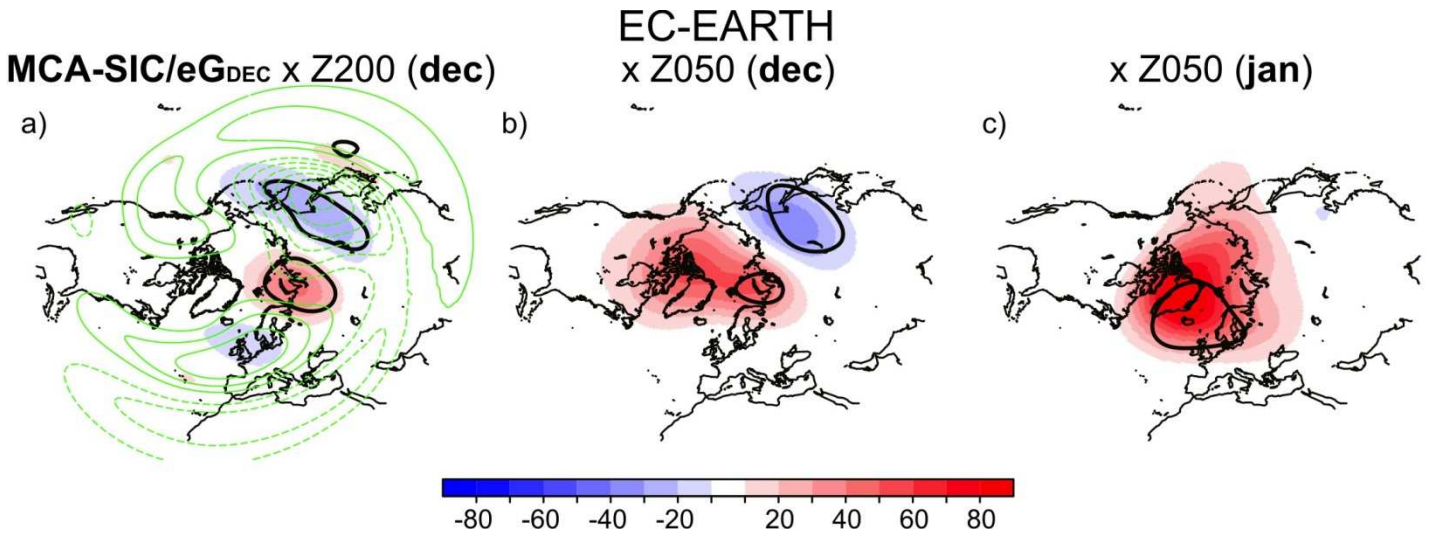


c) **MCA-SIC/eG$_{DEC}$** x SLP (**jan**)



sig.lev.(SC)=5%

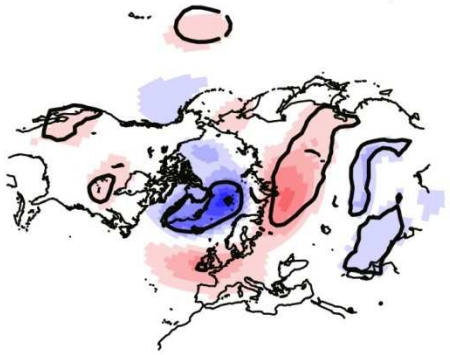




- eG **Dec** / SLP **Jan**: together with the anomalous anticyclone over northern Siberia (Z200), consistent with direct linear response to SIC reduction (see SLP), there is also an apparent downstream propagation of anomalies. the weakening of the polar vortex in Dec (Z050), preceding the establishment of the negative NAO-like patter at surface (in Jan), projects on a wavenumber-2 structure at high latitudes, suggesting as well that a stratospheric pathway could act as driving mechanism. in Jan, the weakening remains

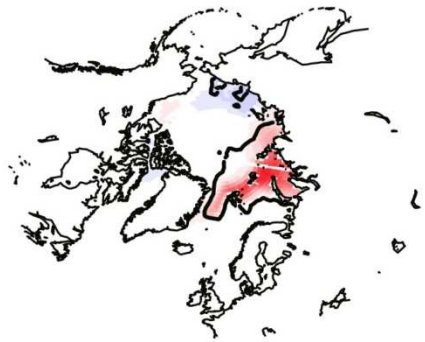
GFDL

a) **MCA-SIC/eG$_{OCT}$ x SLP (oct)**

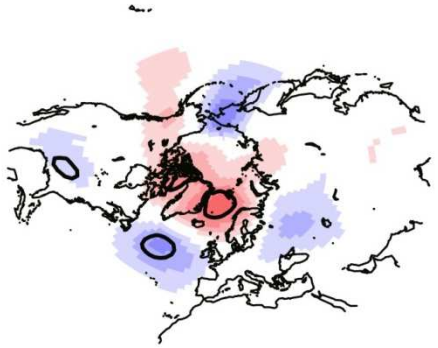


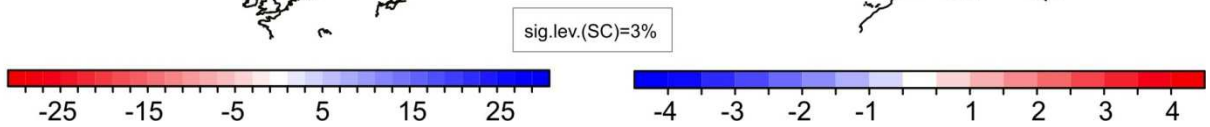
- eG **Oct** / SLP **Nov**: it resembles the observed MCA with SIC in Nov (1-month lag towards negative NAO-like), but different timing – prior to obs (Oct->Nov vs Nov->Dec) vs CNRM and EC-EARTH showing 1-month delay; it also shows anomalous anticyclone over Siberia

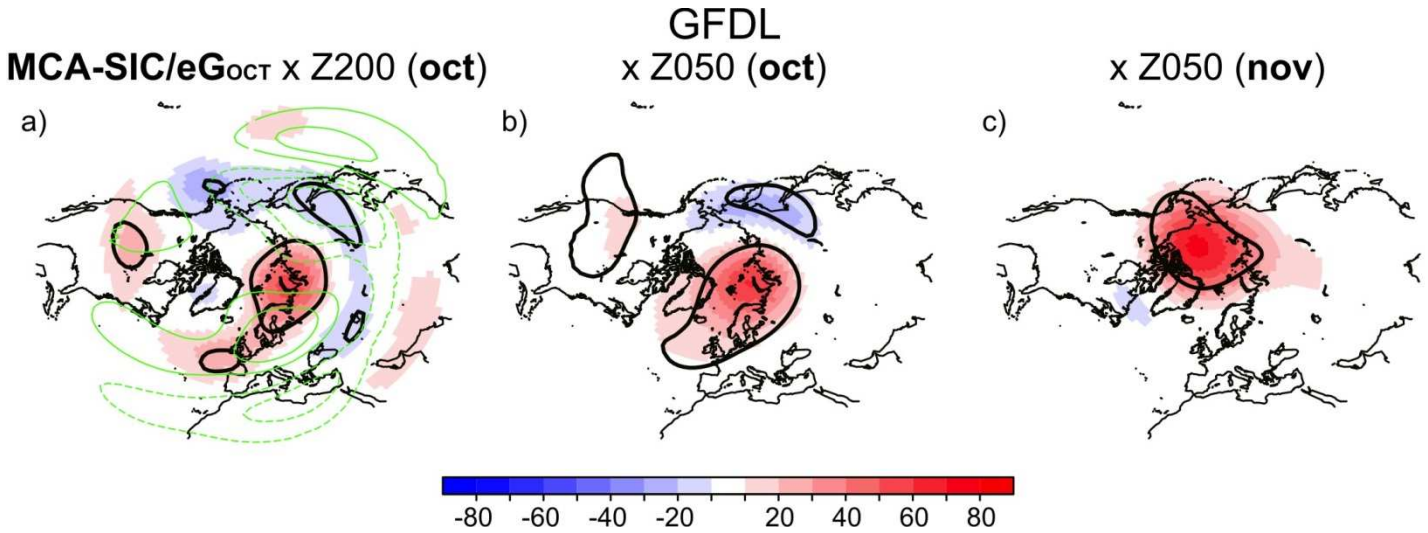
b) **MCA-SIC/eG$_{OCT}$ x SIC (oct)**



c) **MCA-SIC/eG$_{OCT}$ x SLP (nov)**

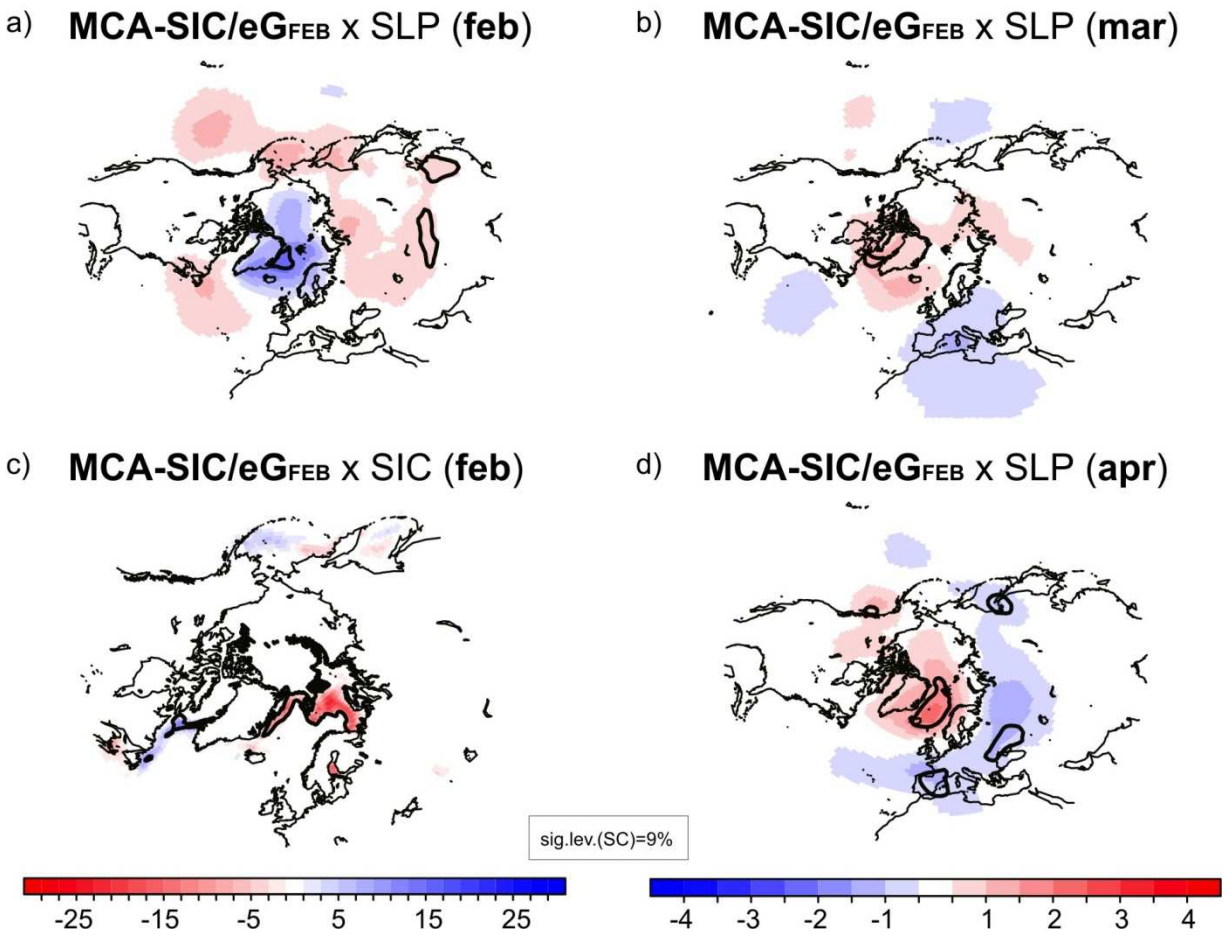




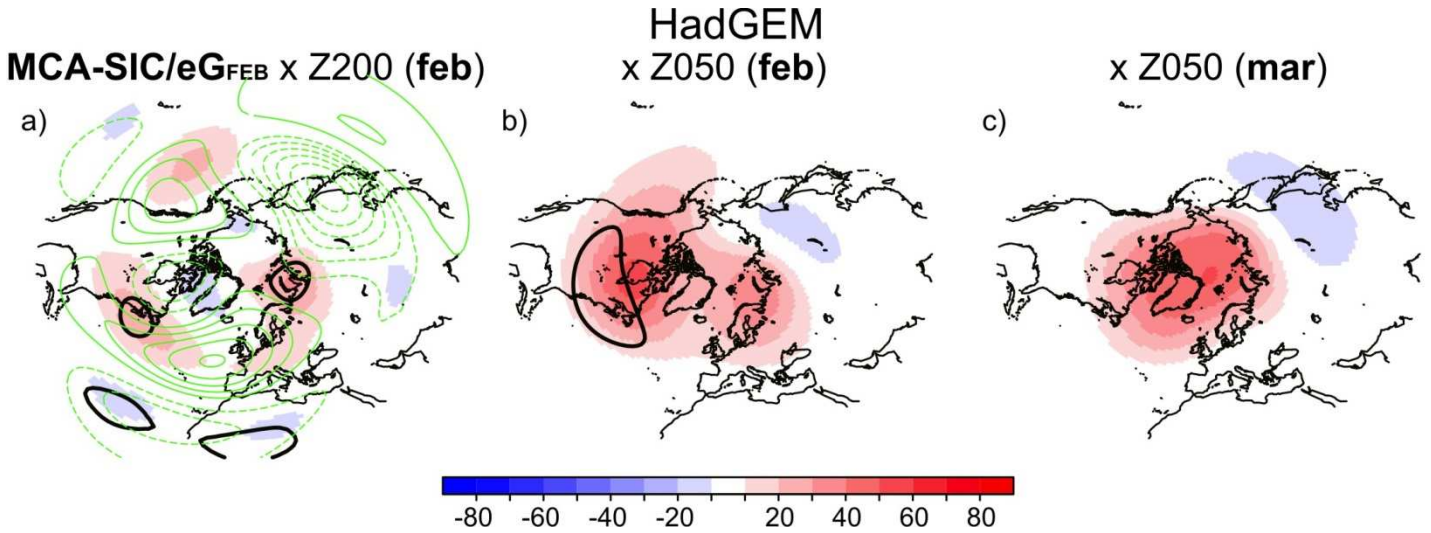


- eG **Oct** / SLP **Nov**: the anomalous anticyclone over northern Siberia (Z200) shows some baroclinicity (cf. SLP), consistent with direct linear response to SIC reduction. there is also an apparent downstream propagation of anomalies. the weakening of the polar vortex in Oct (Z050), preceding the establishment of the negative NAO-like patter at surface (in Nov), is quite barotropic - projecting on a mixture of wavenumber-2 structure and vortex displacement. in Jan, the weakening remains. these results suggest an active role of the stratosphere in driving the lagged negative NAO-like pattern. NOTE: the polar vortex is probably developing at this time (Oct-Nov)

HadGEM



- eG **Feb** / SLP **Apr**: resembles observations with SIC in Dec (2-month lag), with SIC reduction over Greenland-Barents Seas followed by negative NAO-like pattern; in Mar (b) the circulation anomalies already show a negative NAO signature, but not significant – likely eddy-feedback



- eG **Feb** / SLP **Apr**: anomalous anticyclone over northern Siberia (Z200) consistent with direct linear response to SIC reduction (see SLP). there is no clear weakening of the polar vortex in Feb (Z050) – barotropic anomaly over USA, and in Jan it's not significant; it becomes significant in Apr (not shown), once the NAO-like anomaly is established in the troposphere, suggesting that tropospheric dynamics is key in driving the lagged anomalies / eddy-driven

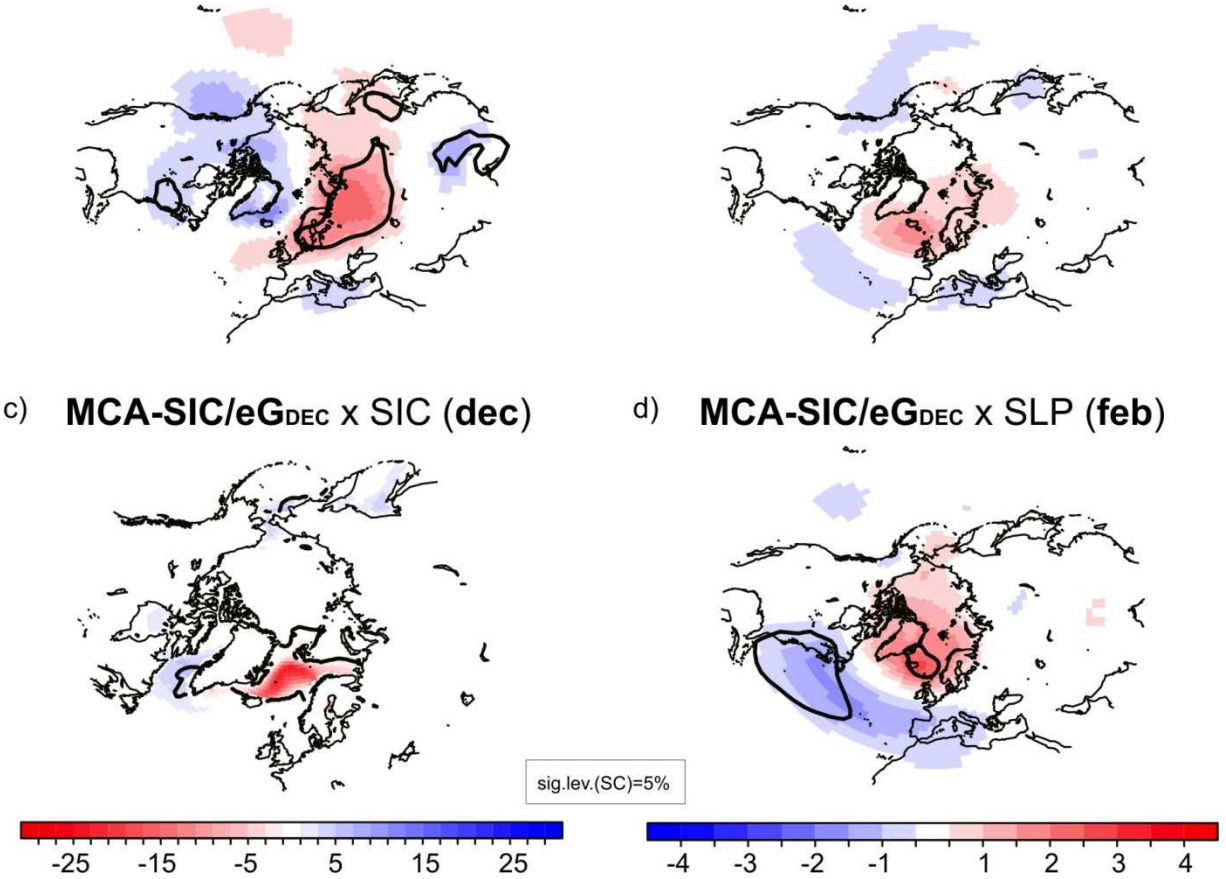
IPSL

a) **MCA-SIC/eG$_{DEC}$** x SLP (**dec**)

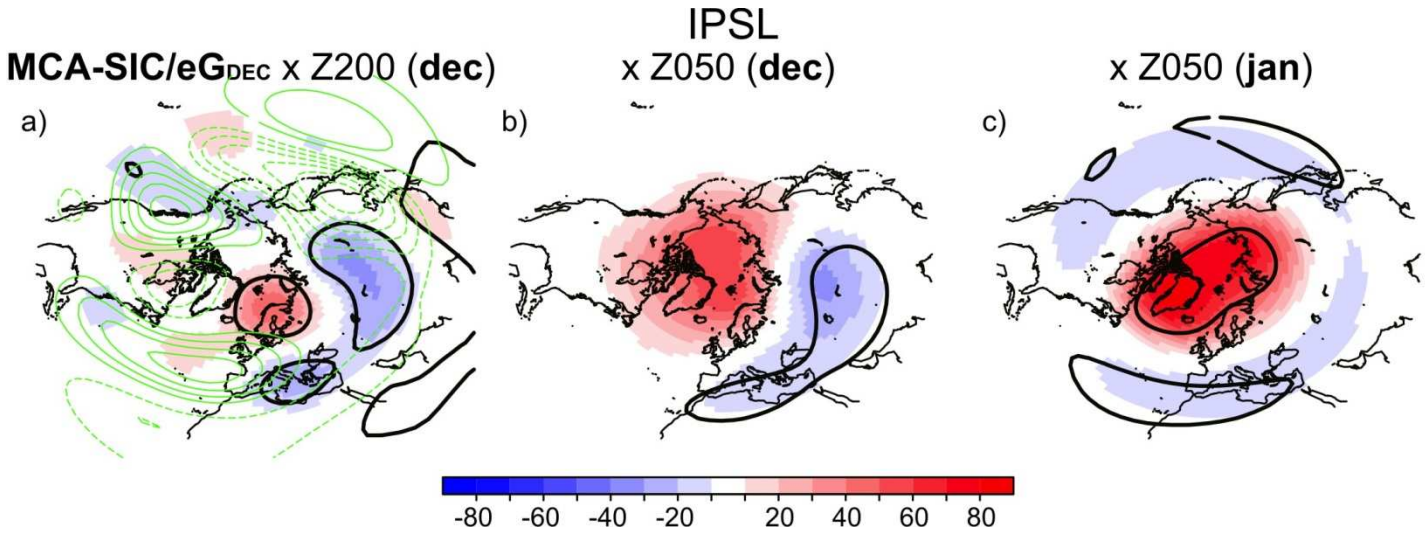
b) **MCA-SIC/eG$_{DEC}$** x SLP (**jan**)

c) **MCA-SIC/eG$_{DEC}$** x SIC (**dec**)

d) **MCA-SIC/eG$_{DEC}$** x SLP (**feb**)



- eG **Dec** / SLP **Feb**: resembles the observed MCA with SIC in Dec (2-month lag), with sea-ice reduction over Greenland Sea followed by negative NAO-like pattern; in Jan (b) the circulation anomalies already show a negative NAO signature, but not significant – likely eddy-feedback



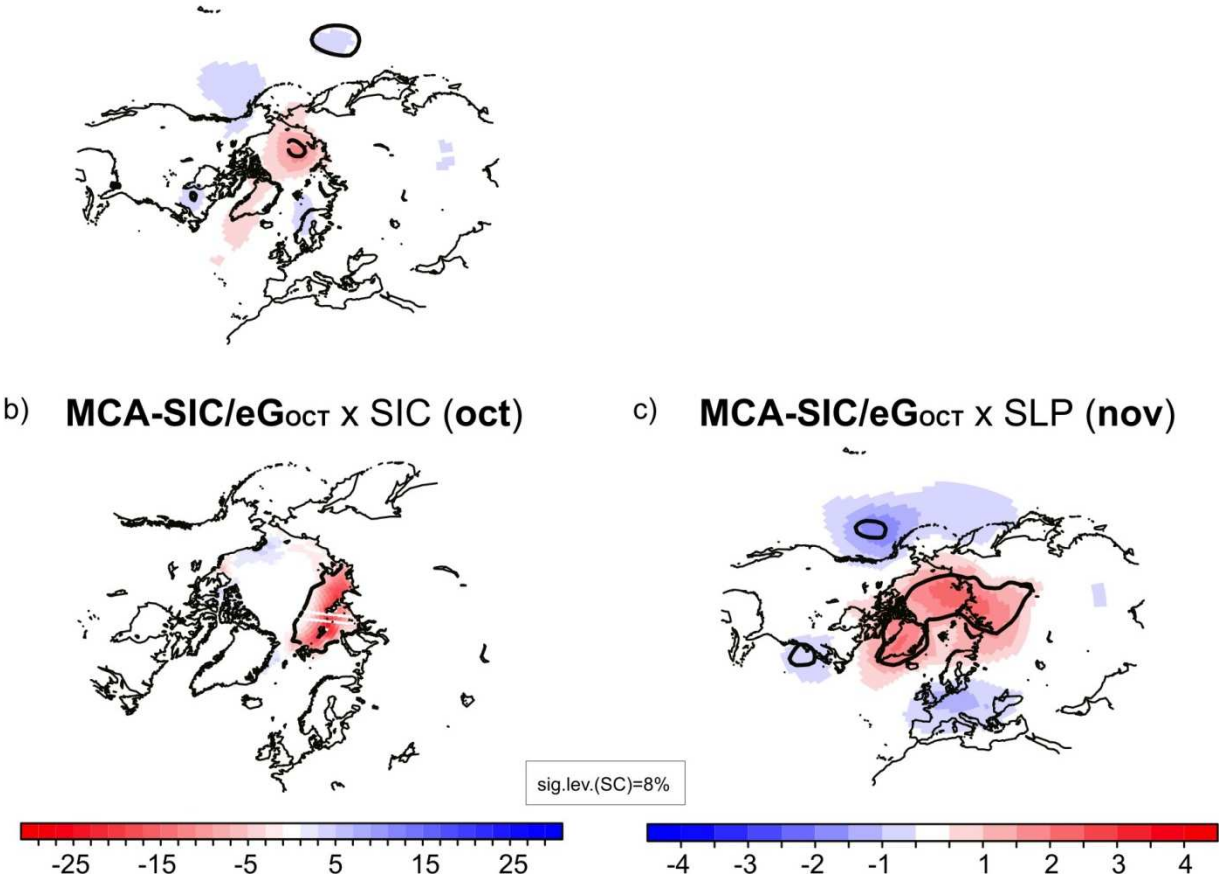
- eG **Dec** / SLP **Feb**: in Dec, anomalous anticyclone over northern Siberia (Z200), consistent with direct linear response to SIC reduction (some baroclinicity, see SLP), there is also downstream propagation towards central Eurasia but no interference with climatological wave. the weakening of the polar vortex in Dec (Z050) is not significant; the weakening in Jan (c) is concomitant with the establishment of a NAO-like pattern at upper-tropospheric levels (Z200, not shown). this suggests that the stratosphere may be playing a feedback role rather than being a driving mechanism for the lagged NAO-like anomaly. the weakening of the polar vortex remains in Feb (not shown), when the North Atlantic SLP anomalies are significant

MPI

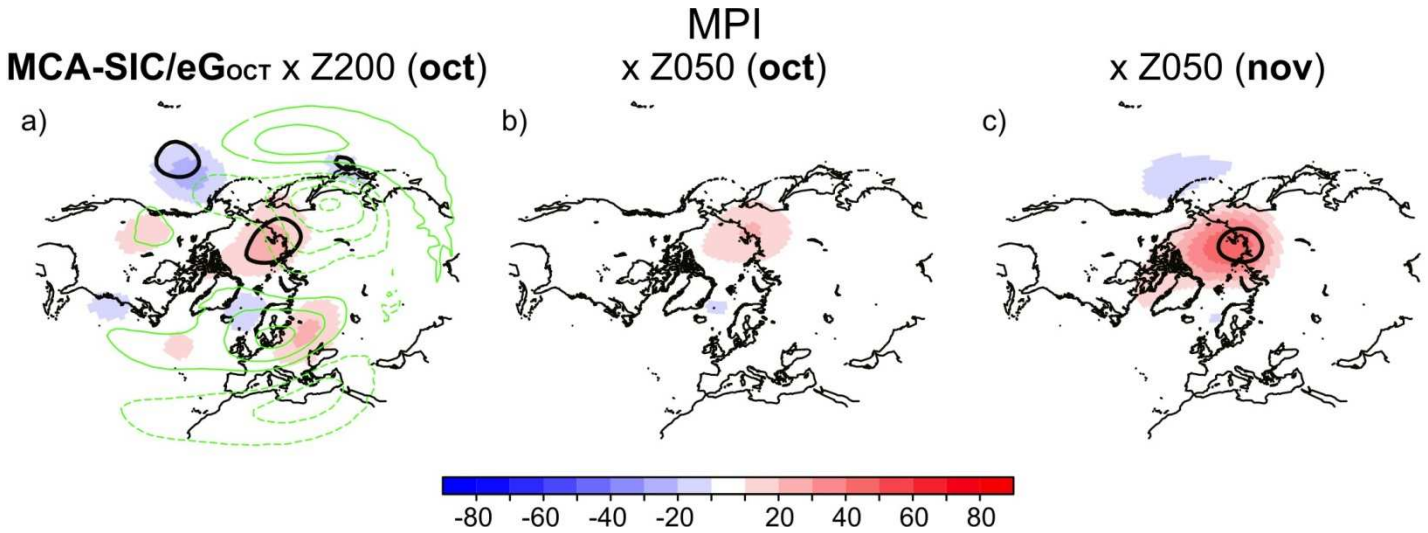
a) **MCA-SIC/eG$_{OCT}$ x SLP (oct)**

b) **MCA-SIC/eG$_{OCT}$ x SIC (oct)**

c) **MCA-SIC/eG$_{OCT}$ x SLP (nov)**



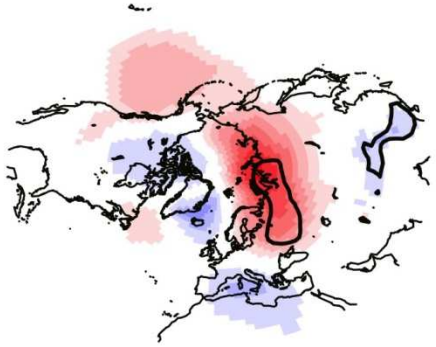
- eG **Oct** / SLP **Nov**: resembles the observational one-month lagged linkage, but with SIC reduction over northern-BK and Laptev Seas.



- eG **Oct** / SLP **Nov**: anomalous anticyclone over northern Siberia (Z200), consistent with response to SIC reduction (cf. SLP), but confined to polar latitudes; this could help interpreting the nagative AO-like pattern established in one month but without stratospheric pathway. no clear weakening of the polar vortex in Oct (Z050) is found, indeed. the polar vortex shows significant anomalies in Nov (c), once the AO has been established; this suggests a dominant role of tropospheric dynamics

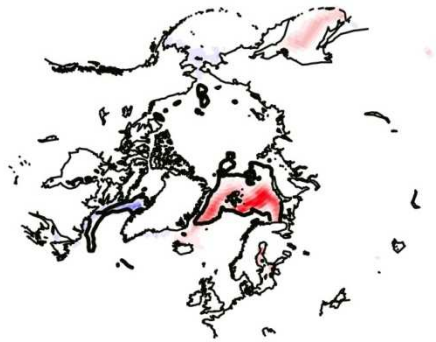
NorESM

a) **MCA-SIC/eG$_{FEB}$** x SLP (**feb**)

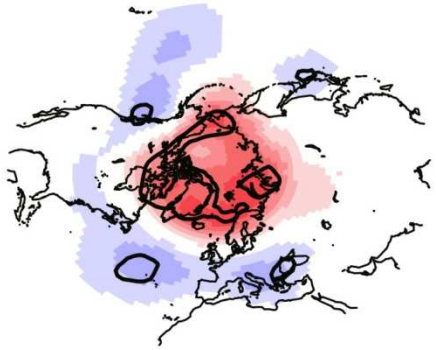


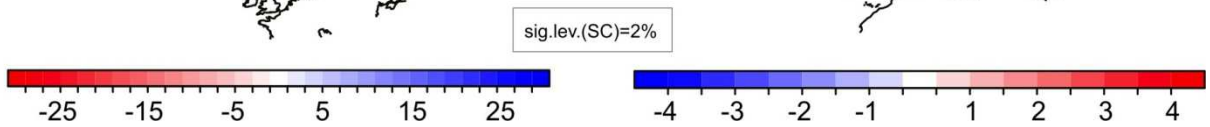
- eG **Feb** / SLP **Mar**: it resembles the observed MCA with SIC in Nov (1-month lag towards negative NAO-like), but different timing – delayed (Feb->Mar vs Nov->Dec), CNRM and EC-EARTH (GFDL) 1-month delay (ahead); it also shows anticyclonic anomaly over Siberia

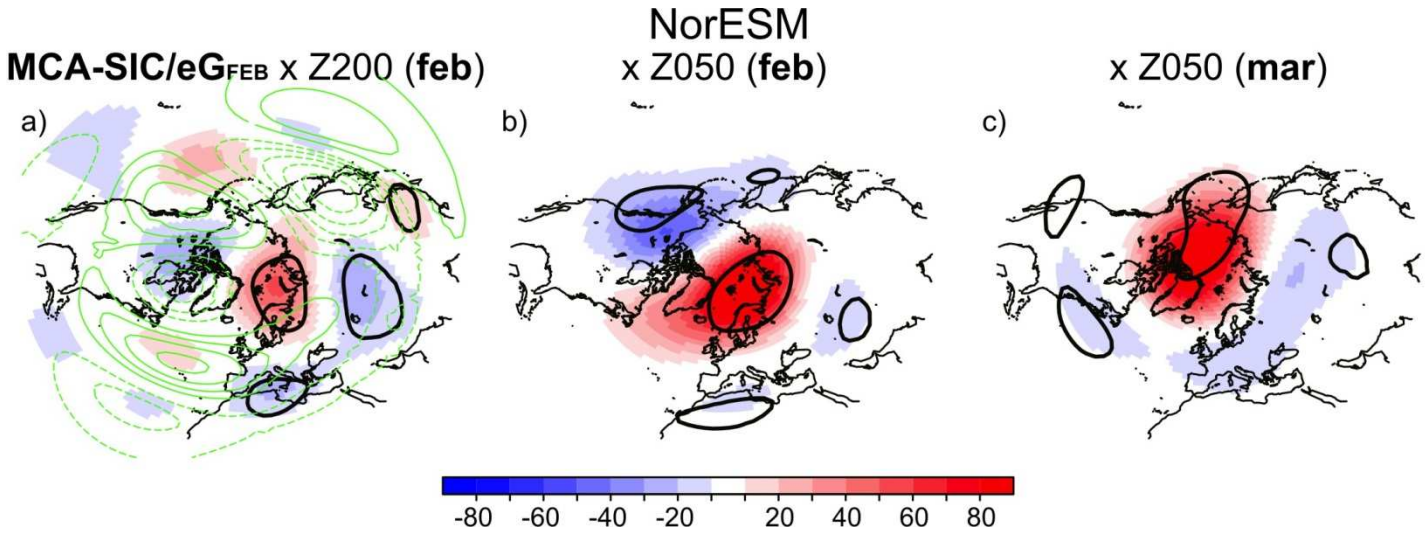
b) **MCA-SIC/eG$_{FEB}$** x SIC (**feb**)



c) **MCA-SIC/eG$_{FEB}$** x SLP (**mar**)







- eG **Feb** / SLP **Mar**: anomalous anticyclone over northern Siberia (Z200), consistent with direct linear response to SIC reduction (cf. SLP), also showing apparent propagation towards Eurasia. the weakening of the polar vortex in Feb (Z050), before the NAO-like pattern establishment (in Mar), shows a clear wavenumber-1 structure, suggestive of a vortex displacement; the weakening of the polar vortex in Mar is also significant. this suggests a potential role of the stratosphere in settling the lagged NAO-like anomaly

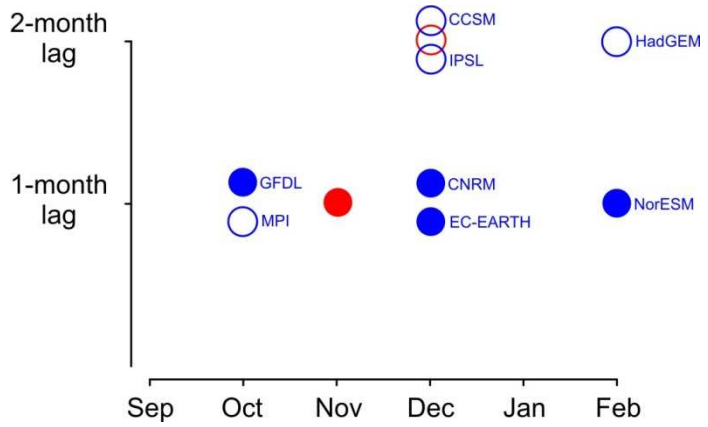
SUMMARY

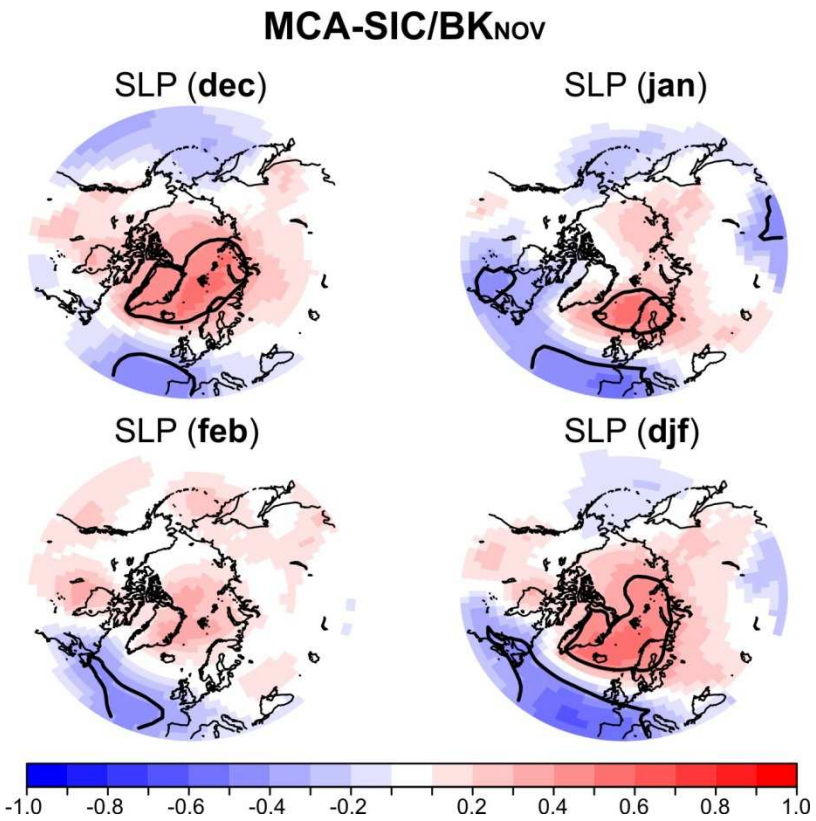
- CMIP5 models analysed here show a significant link with sea-ice reduction over the eastern Arctic (Greenland-Barents-Kara-Laptev Seas) followed by a negative NAO-like pattern

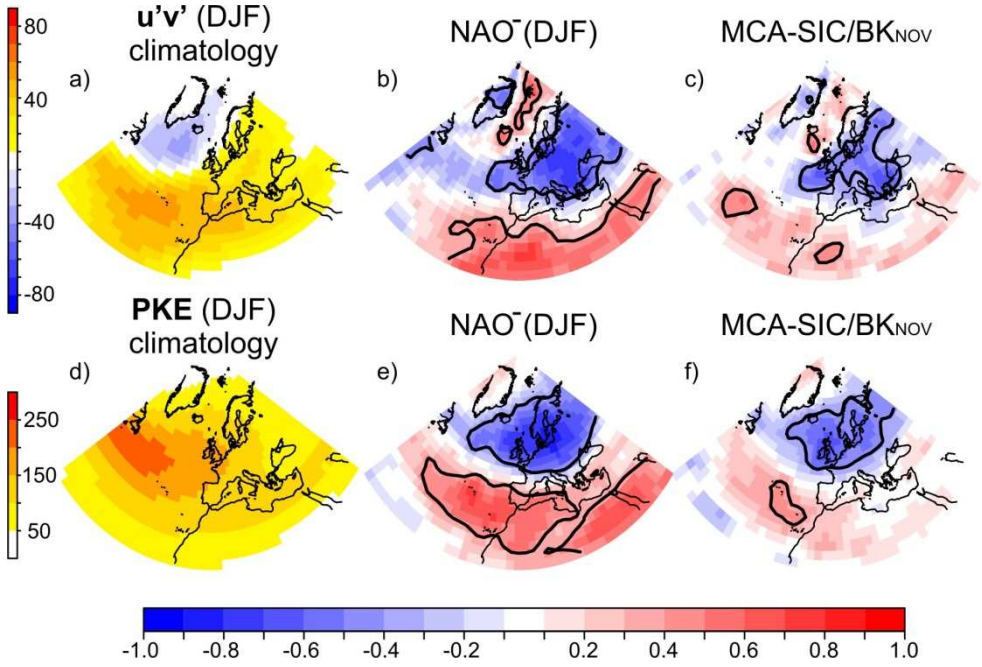
- If the simulated relationship takes *one month* – the results suggest (in general) that a stratospheric pathway could be at play [in observations, this is shown for SIC in Nov]

- If the simulated relationship takes *two months* – the results suggest (in general) that tropospheric dynamics is dominant [in observations, this is shown for SIC in Dec]

- The timing of the simulated relationship strongly depends on the model




MCA-SIC/BKNOV
SLP (dec)
SLP (jan)
SLP (feb)
SLP (djf)
-1.0 -0.8 -0.6 -0.4 -0.2 0.2 0.4 0.6 0.8 1.0


80
40
-40
-80
u'v' (DJF) climatology
a)
NAO⁻(DJF)
b)
MCA-SIC/BKNOV
c)
PKE (DJF) climatology
d)
NAO⁻(DJF)
e)
MCA-SIC/BKNOV
f)
250
150
50
-1.0 -0.8 -0.6 -0.4 -0.2 0.2 0.4 0.6 0.8 1.0